Investigations in the Horsetooth Reservoir project area produced a wealth of data on each of the three sites. These data include structural and non-structural features at each site and thousands of artifacts, of which only a small fraction was collected. When viewed in the aggregate, these data have also expanded our knowledge and understanding of the local history. The results are described below by site.

5.1 SITE 5LR9949

Site 5LR9949 is characterized by a quarry area, seven rooms, two retaining walls, and a well, which are clustered at the base of a rocky talus slope (Figure 5-1).

5.1.1 Site Layout

A detailed map of the site area was created (Figure 5-2). Seven rooms were identified (originally labeled Feature C), extending about 130 ft. from the quarry (Feature B) at an approximate orientation of N65°E (Grid North; hereafter, all directions are referenced to Grid North). An eighth room, originally identified during the survey as Feature E, was no longer visible during the data recovery efforts. Recreationists may have recently moved the rocks.

Figure 5-1. Site Overview at 5LR9949, Looking Northwest.

A large retaining wall (Feature A), approximately 2-3 ft. wide, extends north from the rocky talus for nearly 300 ft., about 30 ft. east of and parallel with the rooms. A smaller retaining wall, about 35 ft. long and about a foot wide, is located about 7 ft. west of the long retaining wall at

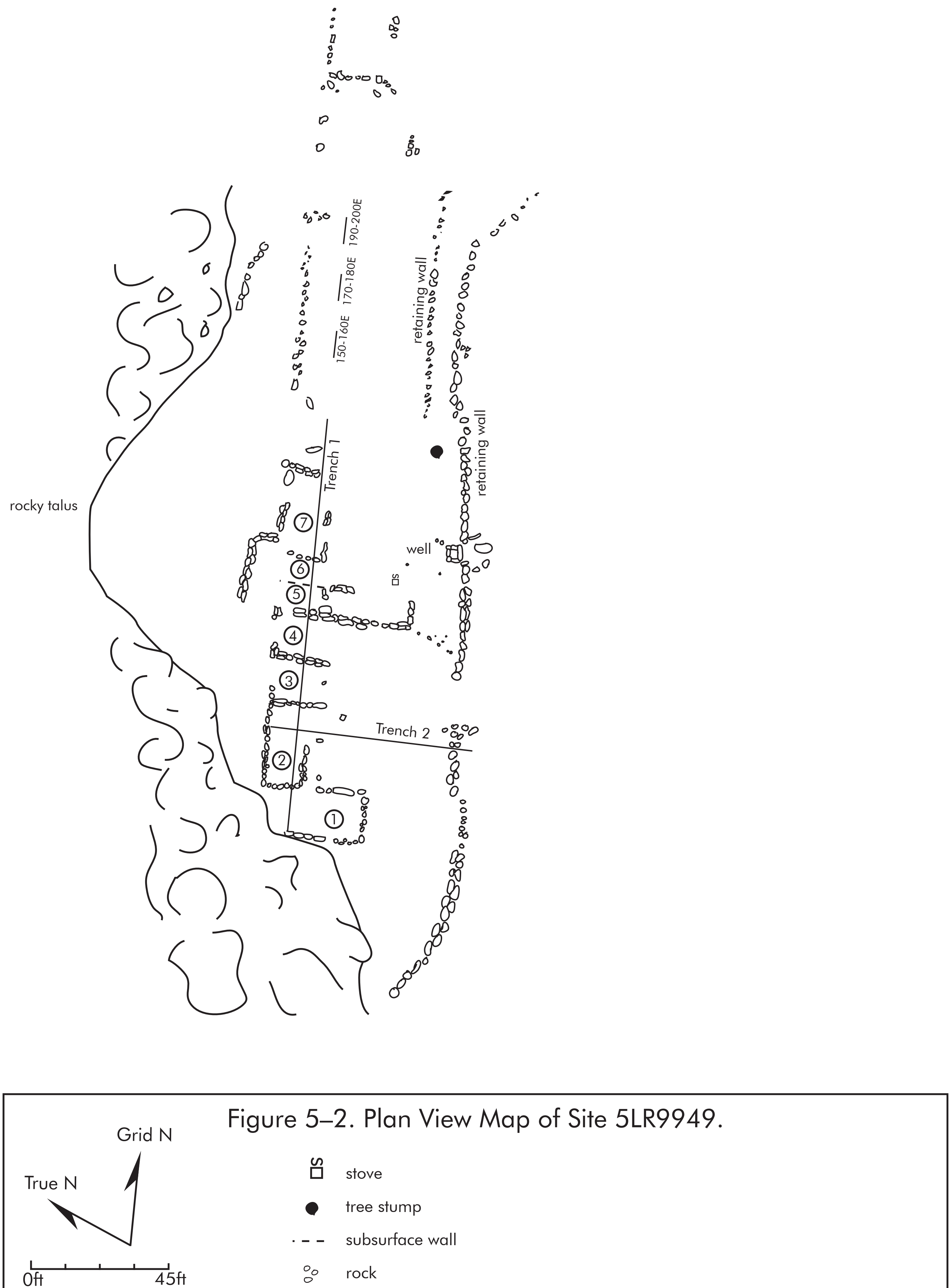


Figure 5–2. Plan View Map of Site 5LR9949.

its northern end. Several short alignments of rock, including one originally described as a retaining wall (Feature D), are found north of the rooms.

A small rock feature fashioned of mortared sandstone blocks is located next to the retaining wall, about 35 ft. east of Room 7. Its upper opening measures 24” by 22”, with a wooden sill on the eastern side that measures 9” wide and 1” thick. The whole feature is slanted back towards the rooms at 10°. The interior space is at least 3 ft. deep, filled with fine-grained sediment. The feature is interpreted to be a well.

Temporally diagnostic artifacts found on the surface of the site include a ceramic fragment with hallmark, dated 1915-1938; bottle base with design patent, dated post-1933; and a bottle base with trademark, dated 1905-1916. Discounting the patent date, the overlap of these age ranges is ca. 1915-1916.

5.1.2 Test Trenches

Two long trenches and three smaller trenches were excavated in prescribed locations on the site. Each trench was 1 ft. wide. Trench 1 is about 140 ft. long and runs through the middle of the seven rooms. Trench 2 is about 70 ft. long, oriented perpendicular to Trench 1 (i.e., about S25°E), and extends from Room 2 to the outer edge of the large retaining wall. Three smaller trenches, each 10 ft. long, were placed at distances of 150-160 ft., 170-180 ft., and 190-200 ft., respectively, from the beginning of Trench 1 along the same alignment. The artifacts found in the test trenches are summarized in Table 5-1. About one-fourth of these artifacts were collected; the remainder were described in the field and returned to the trenches.

5.1.2.1 Trench 1

Trench 1 intersects all seven rooms. It was excavated until a floor or culturally sterile deposits were reached. Figure 5-3 is a stratigraphic profile of the deposits in Room 2. Immediately above the stone floor are *Layers IV* and *V*, which are described as very dark gray and dark gray sand, respectively, each 2-3 inches thick. These two layers probably are sediments that were deposited on the site after filling of the reservoir was completed in January 1951. Above these initial deposits are two markedly different layers: *Layer III* is a thicker (6-14 inches) deposit of compacted, grayish-brown sandy silt with a few small rocks and mortar, while *Layer II* is a thin (2-6 inches) deposit of loosely compacted, coarse red sand containing ample amounts of wall rubble. These two layers probably represent a time when the water level in the reservoir was low enough that the walls collapsed. Low reservoir levels occurred in 1955, 1965, and the late 1970s (Figure 2-4). Finally, the deposit is capped by *Layer I*, a thin (2 inches), discontinuous stratum of yellowish-brown sandy silt, which may correspond to a return to deeper reservoir levels.

<u>Room 1</u> measures about 30 ft. by 15 ft. and has a 3-foot wide opening on the eastern side. Rocky talus forms the southern and western walls of the room. The floor consists of 1” x 6” wooden planks, which are oriented to the long axis of the room and presumably extend the full length. No nail holes were visible in any of the exposed planks. Artifacts recovered from the room include wood pieces (identified as probably Douglas fir), nails, window glass, wood, tarpaper, and a large number of miscellaneous metal pieces (Table 5-1). A nut from a black walnut (*Juglans nigra*) was also recovered. No temporally diagnostic artifacts were found.

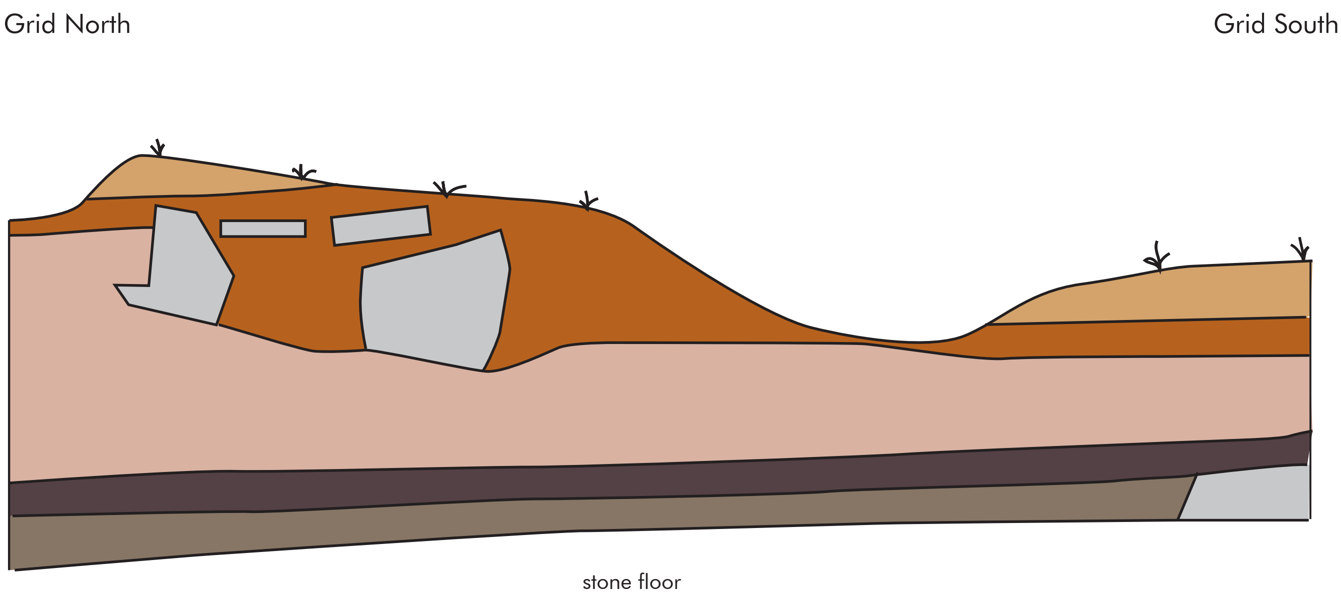


Figure 5–3. Stratigraphic Profile of
Trench 1 in Room 2 at Site 5LR9949, Looking Grid East.

8in
0in 8in

- Layer I: yellowish brown (10YR 5/4) sandy silt with roots
- Layer II: loose, coarse red (10R 4/6) sand with associated cobbles and small boulders
- Layer III: compacted, grayish-brown (10YR 5/2) sandy silt with small rocks and mortar fragments
- Layer IV: very dark gray (7.5YR 3/1) silty sand
- Layer V: dark gray (10YR 4/1) silty sand
- rock
- present ground surface

clay. The few artifacts (wire, a few pieces of window and bottle glass, household and personal items) recovered from this trench were found in Layer 1 (Table 5-1), which is probably a post-reservoir deposit. A trademark on a bottle base near the bottom of Layer 2 exhibited a trademark that is dated to ca. 1920-1964, but was probably deposited before the reservoir began filling (pre-1951).

5.1.2.2 Trench 150-160 East

Trench 150-160 East is an extension of Trench 1 at a distance of 150-160 ft. from the beginning of the trench. It was excavated in 4-inch levels to a depth of about 3 ft. below the present ground surface (bpgs). The soil layers in this segment of Trench 1 are very similar to the East of Room 7 section. Artifacts found in this segment are sparse and consist of nails, bottle glass, ceramics, cartridges, metal, and personal items. The headstamp on a .22 cartridge dates from ca. 1885 to the 1950-1960s. A prehistoric stone flake was found at a depth of about 18 inches bpgs.

5.1.2.3 Trench 170-180 East

Trench 170-180 East is an extension of Trench 1 at a distance of 170-180 ft. from the beginning of the trench. It was excavated in 4-inch levels to a maximum depth of about 22 inches bpgs. Four soil layers were defined in this section of the trench. *Layer 1* (0-6 inches bpgs) is a loosely compacted reddish brown (2.5YR 4/4) silty sand with roots. *Layer 2* (6-8 inches bpgs) is a loose, dark greenish-gray (gley 4/10Y) loamy sand. *Layer 3* (8-9 inches bpgs) is a thin lens of small gravels and reddish brown (2.5YR 4/4) sand. *Layer 4* (9-22 inches bpgs) is a compacted, dark reddish-brown (2.5YR 3/3), fine-grained sand with a moderate amount of gravels and pebbles. The artifacts include mostly bottle glass, with some window glass, and a can, cartridge, and piece of hardware, all recovered from the top 12 inches of deposits (Table 5-1). The .22 cartridge has a headstamp that dates to ca. 1887-1934.

5.1.2.4 Trench 190-200 East

Trench 190-200 East is an extension of Trench 1 at a distance of 190-200 ft. from the southern end of the trench. It was excavated in 4-inch levels to a depth of about 24 inches bpgs. The soil layers in this unit are very similar to Trench 170-180 East. Artifacts were recovered to a depth of approximately 20 inches, but the highest frequency occurred at a depth of about 8 inches bpgs. The artifacts include bottle and window glass, metal and hardware, wire, and a few personal items (Table 5-1). No diagnostic artifacts were found in this section.

5.1.2.5 Trench 2

Trench 2 was laid out perpendicular to Trench 1, running east from the base of the talus slope, through Room 2, and ending just beyond the large retaining wall. It was excavated in 4-inch levels to a general depth of about 12 inches bpgs. At its eastern end, near the retaining wall, the trench was excavated to a depth of about 34 inches bpgs. In this location, seven stratigraphic layers were identified (Figure 5-4). They are numbered sequentially from the bottom to the top of the deposit. *Layer I* (26-34 inches bpgs) is loose, dark reddish brown (5YR 2.5/2) clay. *Layer II* (21-26 inches bpgs) is a very compact, dark brown (7.5YR 3/2) loam with several small sandstone fragments. *Layer III* (19-21 inches bpgs) is a compact, dark brown (7.5YR 3/2) sandy

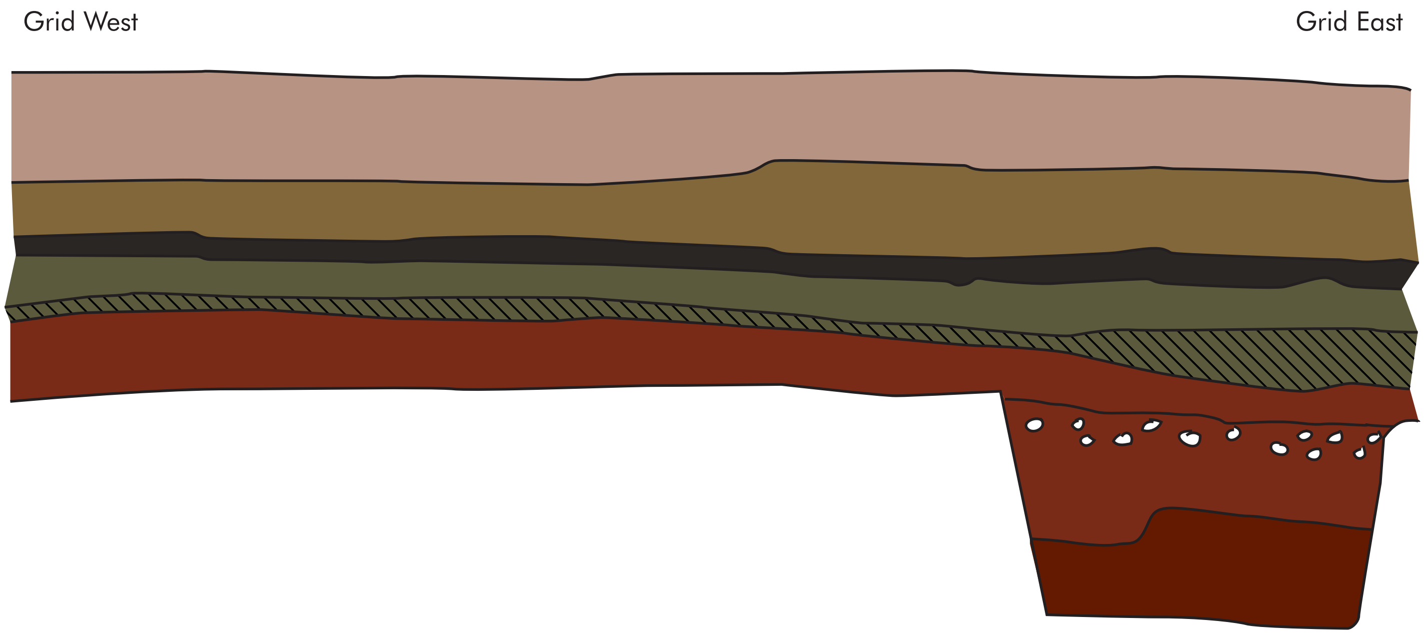
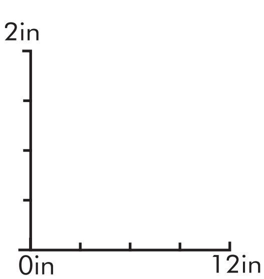


Figure 5–4. Stratigraphic Profile of Trench 2 at Site 5LR9949, Looking Grid North.



- Layer VII: loose, reddish brown (5YR 5/3) silt
- Layer VI: semi-compacted, dark grayish brown (10YR 4/2) loamy silt; 10-20% grass and weed roots; rusty streaks from metal and some mica flakes
- Layer V: loose, very dark gray (2.5YR 3/1) loamy sand; 5-10% grass roots
- Layer IV: crumbly, very dark grayish brown (10YR 3/2) loamy silt or loam; 5-10% grass roots
- Layer III: semi-compacted, dark brown (7.5YR 3/2) sandy loam; 5-10% grass roots, 5% very small pebbles,
- Layer II: very compact and blocky, dark brown (7.5YR 3/2) loam
- Layer I: very loose, dark reddish brown (5YR 2.5/2) clay

loam with very small pebbles. *Layer IV* (13-19 inches bpgs) is a crumbly, very dark grayish brown (10YR 3/2) loamy silt. Cultural materials are concentrated at the base of this layer. *Layer V* (11-13 inches) is a loose, very dark gray (2.5YR 3/1) loamy sand. *Layer VI* (6-11 inches) is slightly compact, dark grayish brown (10YR 4/2) loamy silt with grass roots. *Layer VII* (0-6 inches) is a loose, reddish brown (5YR 5/3) silt with grass roots.

Artifacts were abundant in this trench, comprising over 21 percent of the total number of artifacts from the site, collected and non-collected (Table 5-1). This assemblage includes a considerable amount of bottle glass, window glass, ceramics, nails, cans, wire, cartridges, hardware and metal, household and personal items, apparel and accessories, and faunal and floral remains. The faunal remains consist of rib, long bone, or vertebra fragments from a medium-sized mammal, a fibula fragment from a medium-sized mammal, and a canine tooth from a small- to medium-sized carnivore. The floral remains have been identified as sour cherry (*Prunus cerasus*) or sweet cherry (*Prunus avium*) and watermelon (*citrellus lanatus*) seeds, plum (*Prunus* sp.) pits, and walnut (*Prunus regia*). A tool handle made of hickory (*Carya* sp.) and Douglas fir (*Pseudotsuga menziesii*) wood were also recovered.

The age range for artifacts from Trench 2 is 1917-1949. The age ranges overlap at 1930-1935.

5.1.3 Well

The bottom of the well was probed with a coring tool. The feature contained fine-grained lake sediments. Except for some reservoir-era artifacts (e.g., aluminum cans) near the top, the well deposits are culturally sterile.

5.2 SITE 5LR9961

Site 5LR9961 is described as a circular concentration of historic artifacts (Figure 5-5). The site appears to have been disturbed by unknown parties before it was recorded, and again after it was recorded, but before the data recovery excavations could be conducted.

5.2.1 Site Layout

A plan view map of the site shows the artifact concentration on the edge of a moderate slope (Figure 5-6). The dump was bisected along its north-south axis, surface artifacts collected or described, and the east half excavated to culturally sterile levels.

5.2.2 Excavation Unit (E.U.) 1

Excavation Unit (E.U.) 1 is the east half of the artifact concentration. It was excavated in 4-inch levels to a maximum depth of 24 inches where culturally sterile deposits were encountered. The deepest part of the E.U. is towards the center, and it tapers up to depths of about 5-6 inches on the northern and southern ends of the unit. As illustrated in a stratigraphic profile of the west wall of E.U. 1 (Figure 5-7), four discrete strata are evident (numbered from bottom to top). *Layer I* (20-24 inches bpgs) is a moderately compacted to loose, brown (10YR 4/3) lens of sandy loam with coarse gravel. It pinches out to the north and south. *Layer II* (13-20 inches bpgs) is a moderately compacted, yellowish brown (10YR 5/8) silty-clay loam. *Layer III* (5-13 inches bpgs) is a moderately compacted, dark yellowish brown (10YR 4/4) silty-clay loam with a small

Figure 5-5. Overview of Site 5LR9961, Looking West. Trash Pit is Located Above and to the Right of the Roll of Barbed Wire.

amount of fine- to medium-sized gravels. *Layer IV* (0-5 inches) is moderately compacted, yellowish brown (10YR 5/4) clay loam with a small amount of very fine gravels. After consideration of the slope angle of larger sandstone rock fragments and the stratigraphy, it is clear that artifacts were deposited down a shallow slope rather than in some kind of pit.

Table 5-2 summarizes the artifacts found in E.U. 1. About one-fifth of the artifacts were collected. The remainder were described and counted and placed back in the pit. Bottle glass is by far (57 percent) the most abundant artifact recovered from the unit, followed by cans (22 percent). Modest percentages of ceramics (7 percent), nails (5 percent), and hardware (3 percent) are also present. Slightly more than half of the artifacts were recovered from the surface of the unit. The frequency of artifacts generally declines with depth, except for very slight increases in Levels IV and V.

The artifact assemblage includes a sizable number of temporally diagnostic artifacts. The initial and final mean manufacturing dates for these artifacts are 1922 and 1941, respectively.

Faunal materials in the assemblage include a sawn scapula and sawn rib or long bones from a large mammal in Level I. In Level IV, several bone fragments of a medium to large mammal were found, as were various bones from a pheasant. Level V contains several medium to large mammal bone fragments, as well as bones from a female bird, perhaps the same pheasant found in Level IV.

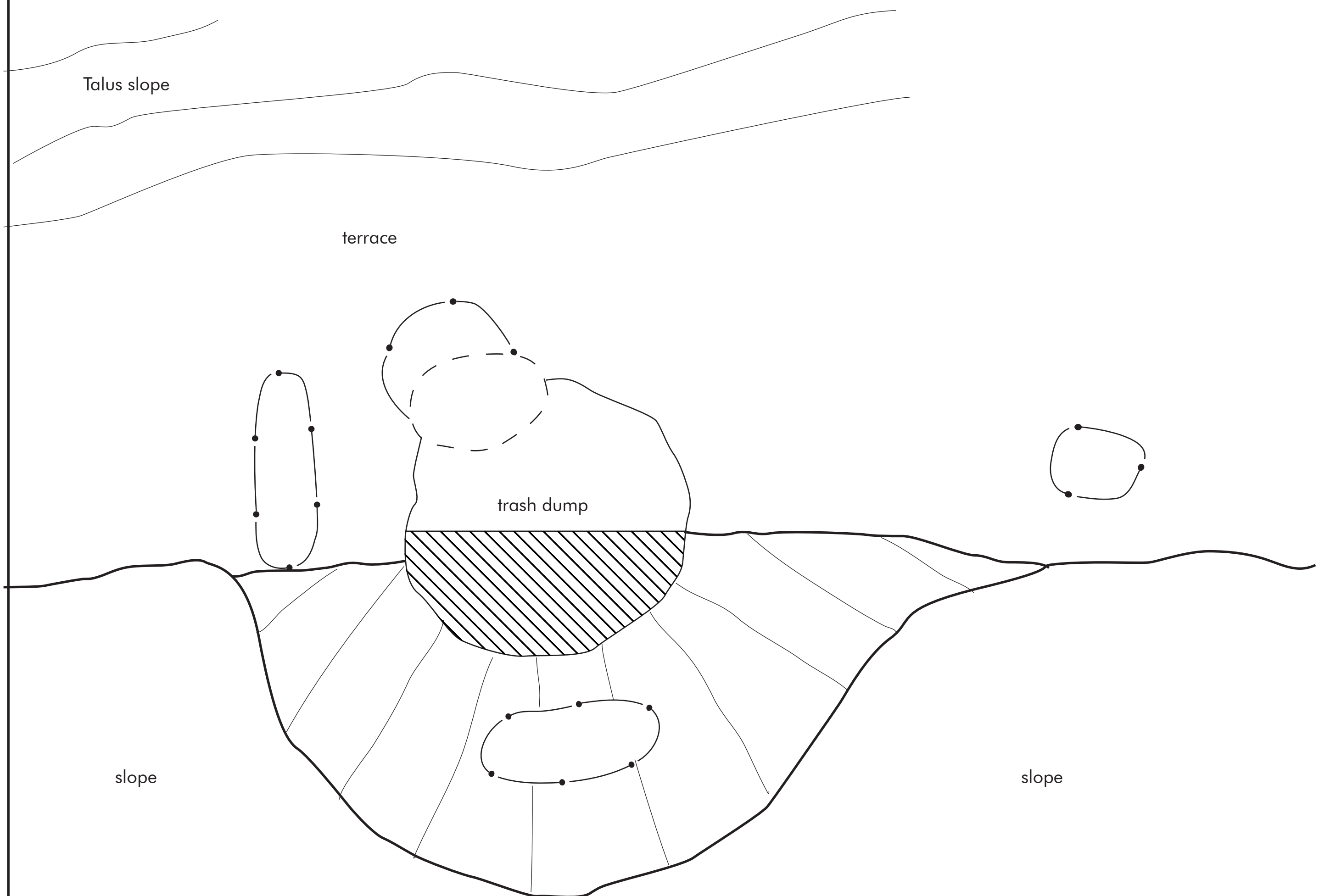


Figure 5–6. Plan View of Site 5LR9961.

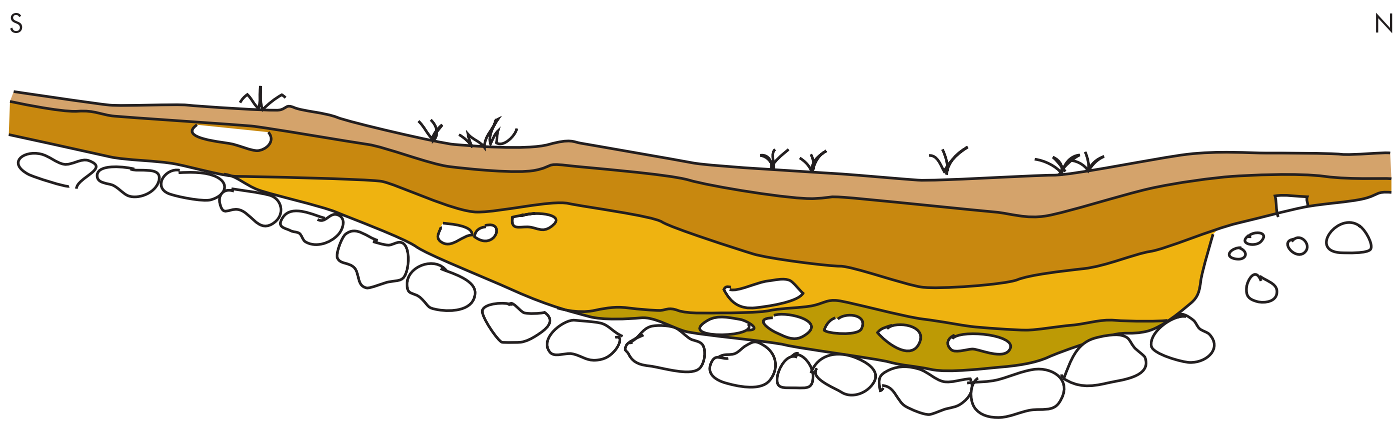


Figure 5–7. Stratigraphic Profile of
Excavation Unit 1, at Site 5LR9961, Looking West.

5in

0in 10in

rock

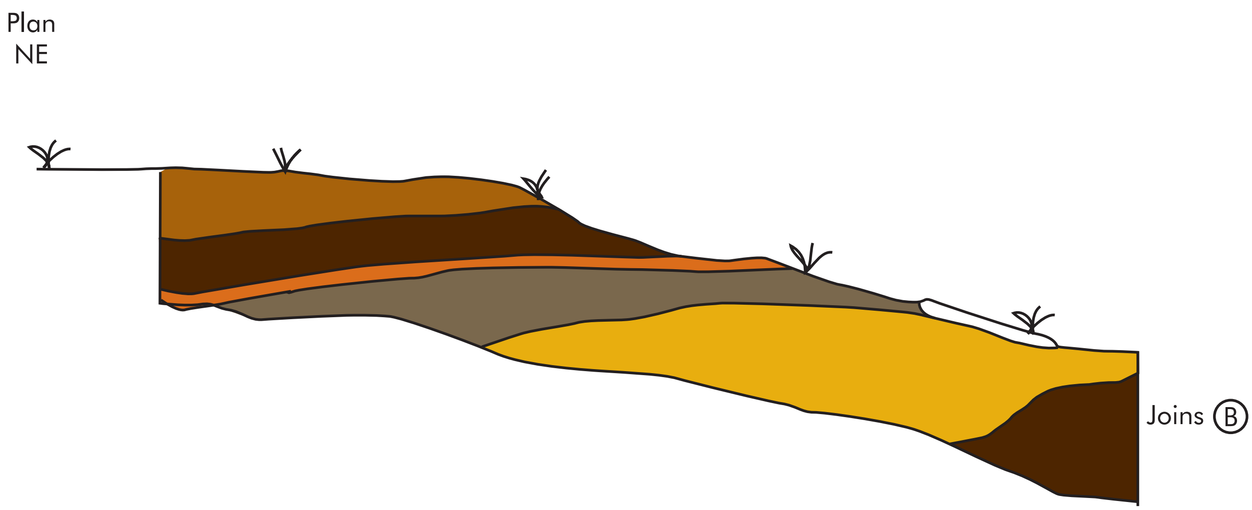
present ground surface

Layer I: brown (10YR 4/3) sandy loam, angular and subangular coarse gravel; rusty metal fragments

Layer II: yellowish brown (10YR 5/8) silty clay loam; rusty metal fragments

Layer III: dark yellowish brown (10YR 4/4) silty clay loam with fine to medium angular gravels

Layer IV: yellowish brown (10YR 5/4) clay loam with very fine angular gravels



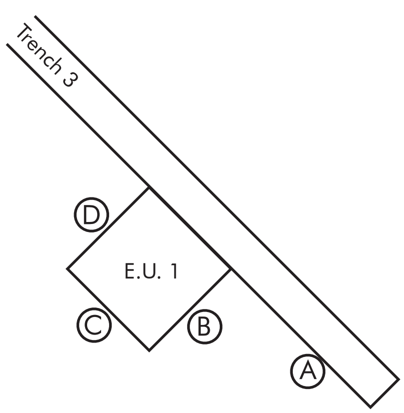


Figure 5–10. Profile A, Trench 3, 5LR9974.

present ground surface

stone

reddish brown (5YR 4/3) coarse sand, loose

brown (7.5YR 4/3) silt, compact

dark reddish brown (5YR 3/2) clay, moderately compact

mottled yellowish brown (10YR 5/6) and black silt (cultural horizon) moderately compact

red (2.5YR 5/6) clay lens, moderately compact

dark reddish brown (5YR 3/2) clay, moderately compact

0ft 1ft

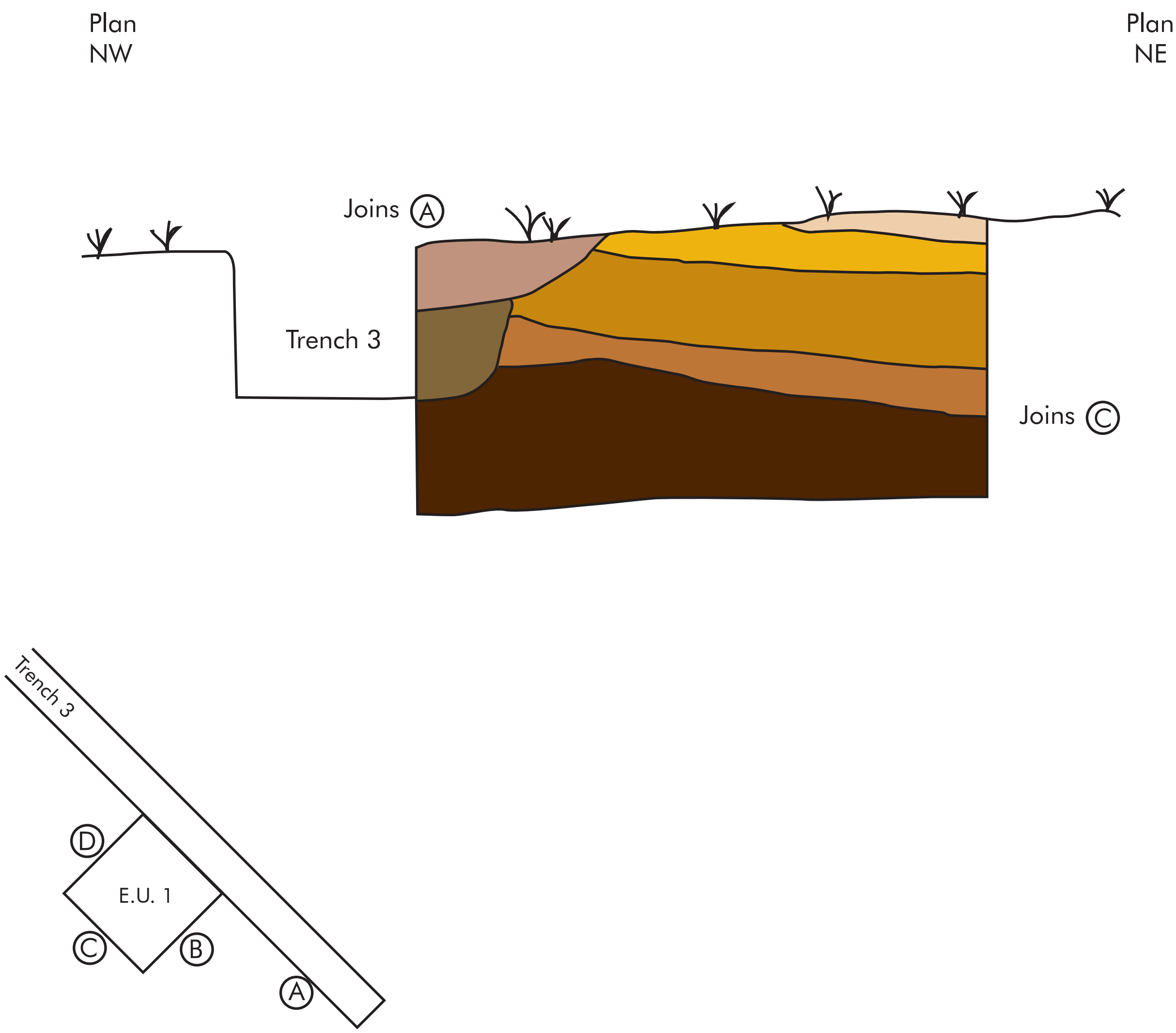


Figure 5–11. Profile B, Trench 3, North Wall, EU 1, 5LR9974.

- very pale brown (10YR 7/4) sand, loose
- mottled yellowish brown (10YR 5/6) and black silt, moderately compact **(cultural horizon)**
- mottled dark yellowish brown (10YR 4/4) charcoal and ash (10YR 6/1) silt, moderately compact **(cultural horizon)**
- reddish brown (5YR 5/4) coarse sand, loose
- dark reddish brown (5YR 3/2) clay, moderately compact
- brown (10YR 5/3) silt, loose
- dark grayish brown (10YR 4/2) silt, moderately compact
- present ground surface

0ft 1ft

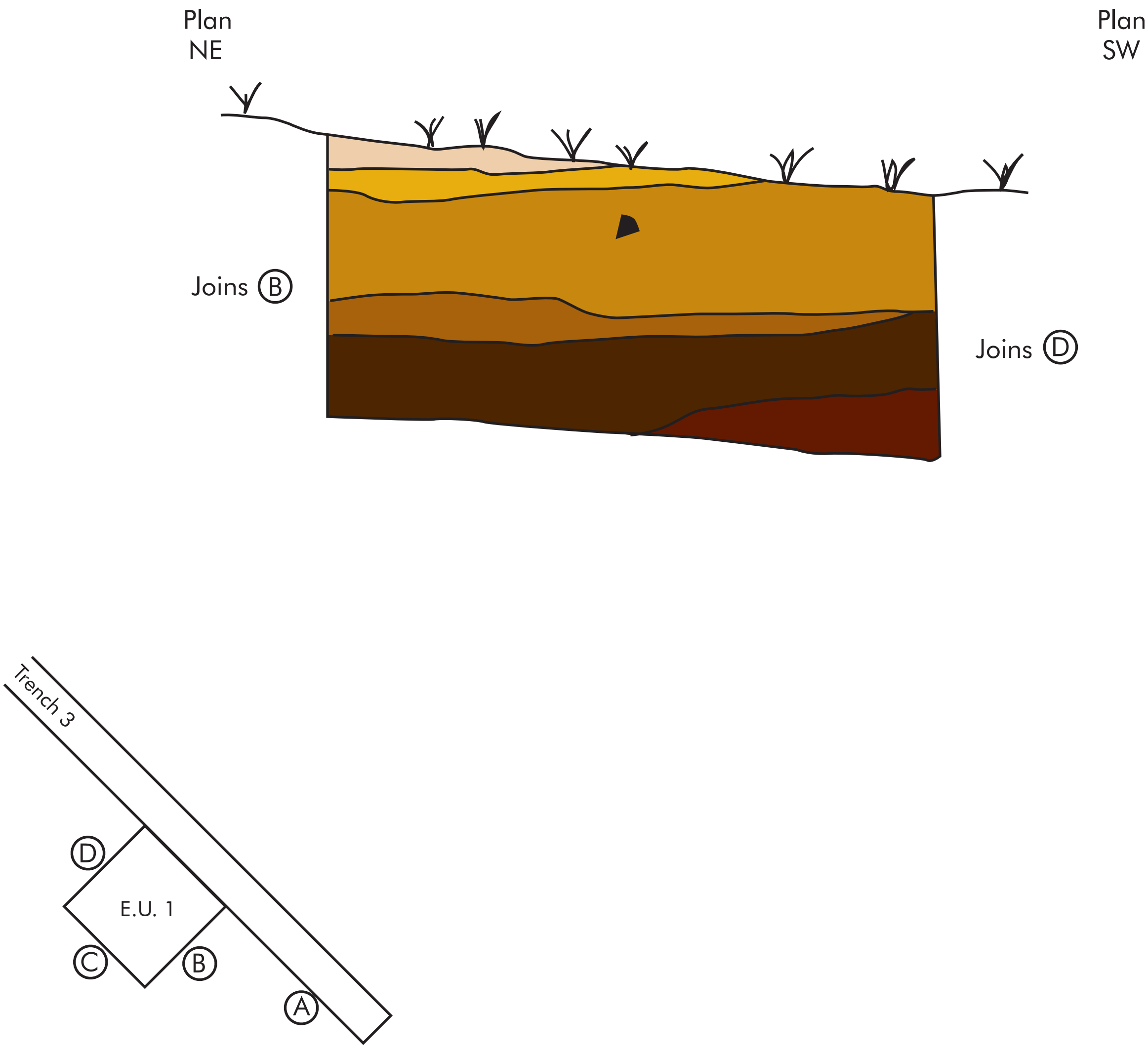


Figure 5–12. Profile C, Trench 3, East Wall, EU 1, 5LR9974.

- present ground surface
- very pale brown (10YR 7/4) sand loose
- mottled yellowish brown (10YR 5/6) and charcoal silt, moderately compact
- mottled dark yellowish brown (10YR 4/4) charcoal and ash silt, moderately compact
- brick fragment
- reddish brown (5YR 4/4) coarse sand, loose
- dark reddish brown (5YR 3/2) clay, moderately compact
- dark reddish brown (5YR 2.5/2) clay, moderately compact

0ft 1ft

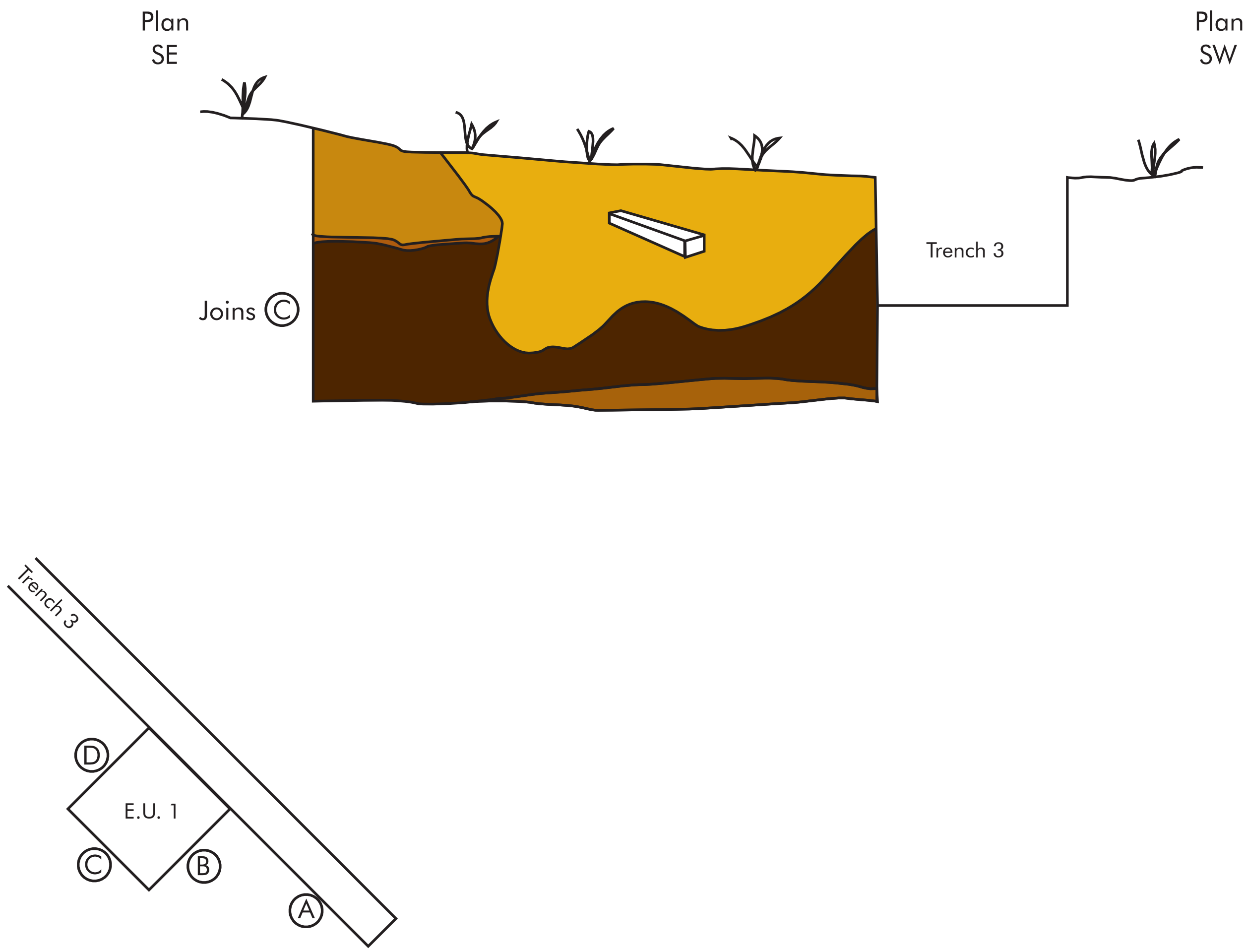


Figure 5–13. Profile D, Trench 3, South Wall, EU 1, 5LR9974.

- mottled yellowish brown (10YR 5/6) and charcoal silt, moderately compact **(cultural horizon)**
- mottled dark yellowish brown (10YR 4/4) charcoal and ash silt, moderately compact **(cultural horizon)**
- reddish brown (5YR 4/4) coarse sand, loose
- dark reddish brown (5YR 3/2) clay, moderately compact
- reddish brown (5YR 4/3) fine sand, moderately compact
- rock
- present ground surface

0ft 1ft

5.3.3.3 Excavation Unit 3

E.U. 3 was placed a few feet north of the intersection of Trenches 1 and 2 where artifacts seemed to be slightly more abundant. Two levels of the unit were excavated to 8 inches below the present ground surface. The soil is described as moderately compacted reddish brown (5YR 5/3) coarse sand with pockets of dark reddish brown (5YR 3/3) and very dark gray (7.5YR 3/1) clay loam. The artifact yield was very low, consisting of mostly bottle glass, but a sawn tibia from a medium to large mammal was also recovered (Table 5-3). Two peach (*Prunus persica*) pits were also recovered. Excavations in the unit were discontinued at the bottom of Level 2.

5.3.3.4 Excavation Unit 4

E.U. 4 was set up on the western side of the northern end of Trench 1, where a scatter of building stone was visible on the surface. The unit was excavated to a depth of 4 inches, at which point an alignment of large sandstone blocks became visible. This alignment, a portion of a building foundation (Structure 2), was completely exposed and is described further below. The soil in E.U. 4 consists of a compacted dark reddish brown (5YR 3/2) clay. At the bottom of the unit, a modest number of artifacts were recovered, including bottle glass, hardware, nails, and household items (Table 5-3). A trademark on a glass bottle base is dated 1929-1949. The assemblage also includes the ribs, long bone (with cut marks), and possible sternum of a medium-sized bird. Floral remains include sour cherry (*Prunus cerasus*) or sweet cherry (*Prunus avium*) seeds, a pumpkin seed, and a sunflower seed.

5.3.3.5 Excavation Unit 5

E.U. 5 was placed on the north side of Trench 2 towards the western end near a modest concentration of building mortar. It was excavated to a depth of 4 inches. The soil is a moderately to strongly compacted very dark gray (7.5YR 3/1) clay loam with a few pebbles. Excavations were discontinued due to an extremely low artifact yield (Table 5-3).

5.3.3.6 Excavation Unit 6

E.U. 6 was placed towards the southern edge of the site, where historic maps indicated that parts of the Wathen Ranch were once located. The unit was excavated to a depth of 44 inches. A stratigraphic profile of one wall of the unit revealed a complex sequence of natural strata (Figure 5-14). The natural layers consist of yellowish brown (10YR 5/4), dark yellowish brown (10YR 4/4), and dark brown (10YR 3/3) sand, silt, and clay. These layers probably reflect different levels of the reservoir in Inlet Bay, when the silts and clays were deposited in deep waters and the sands in shallow waters. A thin cultural horizon consisting of a loosely compacted dark brown (7.5YR 3/3) sand was discerned at a depth of 36-40 inches below the present ground surface. A few pieces of bottle glass and metal were recovered from this level (Table 5-3), which pre-dates the reservoir and may be associated with the Wathen Ranch. Several artifacts found above this horizon include plastic and other “modern” (i.e., post-reservoir) trash.

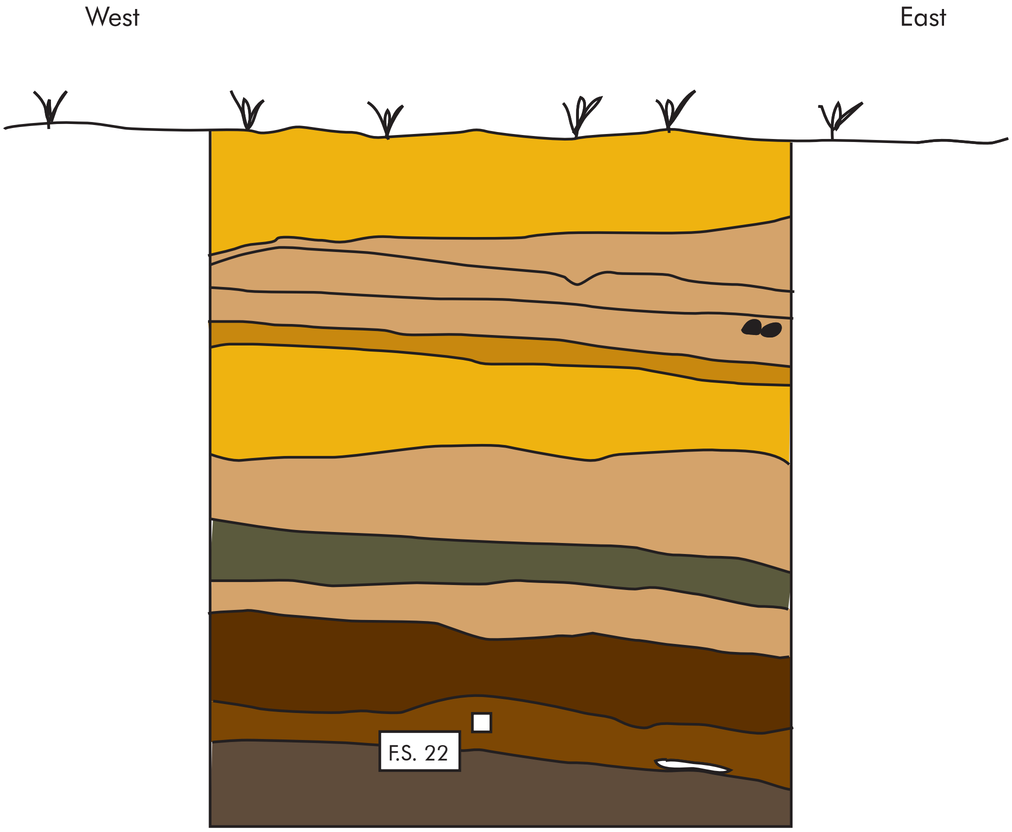


Figure 5–14. Stratigraphic Profile of EU 6, 5LR9974, Looking North.

- Layer I: very dark brown (7.5YR 2.5/2) sandy silt; moderately compact.
- Layer II: dark brown (7YR 3/3) coarse sand; loose **(cultural horizon)**
- Layer III: dark yellowish brown (10YR 3/4) silt; slightly compacted
- Layer IV: yellowish brown (10YR 5/4) sand; loose
- Layer V: dark brown (10Yr 3/3) clay; moderately compact
- Layer VI: yellowish brown (10YR 5/4) sand loose
- Layer VII: yellowish brown (10YR 5/6) clay; compacted with prismatic structure
- Layer VIII: dark yellowish brown (10YR 4/4) fine -grained sand; slightly compacted; microlaminations
- Layer IX: yellowish brown (10YR 5/4) sand, loose; large pebbles; microlaminations
- Layer X: yellowish brown (10YR 5/4) silt, slightly compacted; microlaminations
- Layer XI: yellowish brown (10YR 5/4) fine-grained sand; slightly compacted; microlaminations
- Layer XII yellowish brown (10YR 5/6) clay; compacted with prismatic structure
- pebbles
- metal
- soil sample
- present ground surface

0ft 1ft

5.3.4 Structural Remains

The remains of two structures, here labeled Buildings 1 and 2, were exposed in Trench 4 and E.U. 4, respectively. They are described further below.

5.3.4.1 Building 1

Building 1 consists of two segments of a stone foundation (Figure 5-15), which were discovered during the excavations in Trench 4. The first segment is about 15 ft. long, 18 inches wide, and oriented to magnetic North (N14°E). Part way along this segment is the beginning of a stub wall that extends west for an unknown distance. Slightly more than 4 ft. east of the northern end of the main wall is a shorter wall segment, which is about 3 ft. long, 18 inches wide, and oriented to magnetic North (N14°E). The two wall segments are made of large sandstone blocks held together with gray, fine-grained mortar.

With the exception of bones from a domestic cat (which may have expired underneath the house), artifacts recovered in association with the foundation are sparse. They include nails, roofing materials, batteries, and window glass.

Building 1 corresponds closely to the location of a building labeled “Stone House” on a historic map of the site, dating to the 1940s.

5.3.4.2 Building 2

Building 2 is the stone floor and walls of a small structure, which is located at the northern end of Trench 1, about 40 ft. north of Building 1. The building measures approximately 10 ft. long (north-south) by 8 ft. wide (east-west), and like Building 1, is oriented to magnetic north (i.e., N14°E) (Figure 5-16). The floor is made of large, closely fitted slabs of sandstone, while the walls are constructed of sandstone blocks that are held together with fine-grained, gray mortar. Although portions of the walls fell inward, most fell outward into jumbled piles around the perimeter of the building. Three small circles, each one about 2 inches in diameter, are etched into the floor in the southern half of the building. Although a fourth circle could not be found that would complete the square, it is possible that a small table made these marks. This table would have measured about 2 ft. by 1.5 ft., had metal legs, and stood next to the east wall. Opposite these marks, near the base of the west wall, is a metal hook with wire that may have been used as a tie-down.

Artifacts found in association with the building include small amounts of roofing materials (wooden shingles and tarpaper), a caster, button, and bottle glass. The roofing materials and glass were discovered underneath wall fall, just above the floor, at the southern end of the building. The button was found at the southeast corner, while the caster was found along the eastern wall near the northern end of the building.

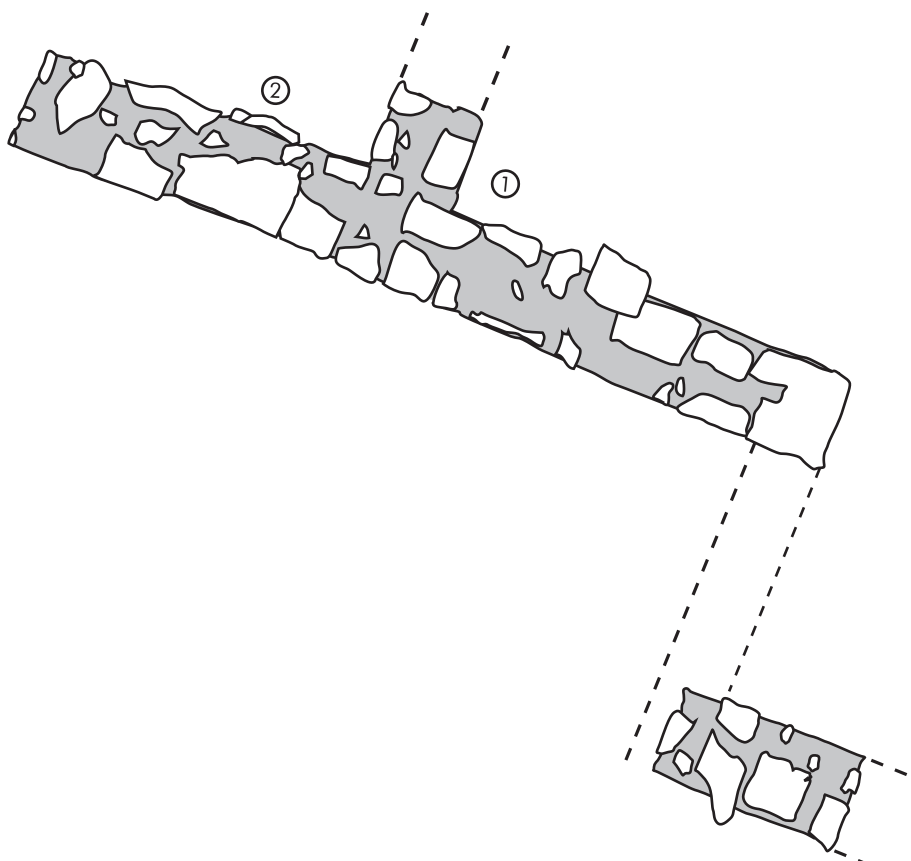


Figure 5–15. Detailed Plan View of Building 1, 5LR9974.

Plan North
True North
Magnetic North

0ft 3.3ft

1 boards, wall fall, nails, and flat glass

2 domestic cat bones

stone

mortar

interpreted extension of wall

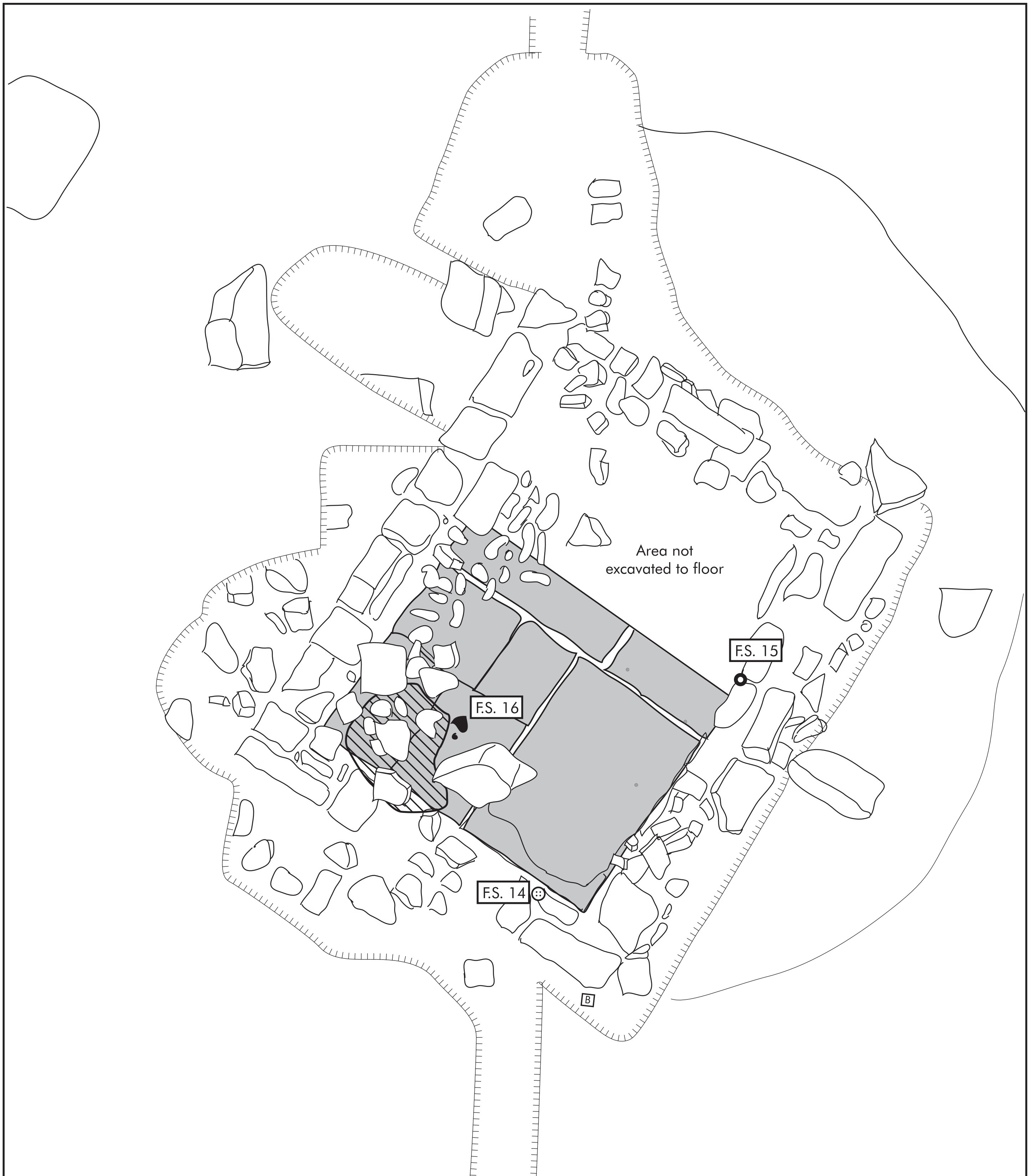


Figure 5–16. Detailed Plan View of Building 2, 5LR9974.

True North
Grid North
0ft 2.5ft

caster (F.S. 15)
bottle glass (F.S. 16)
wood shingles and roofing tiles
brick
button (F.S. 14)
excavation area
table foot spot

5.4 CONSTRUCTION PATTERNS

In addition to the data recovery plan and excavation, the scope of work for this project included a provision to analyze the construction pattern at Horsetooth Reservoir relative to construction methods that would be used today. To accomplish this task, historic sources, site descriptions, construction photographs, and aerial photographs were used to describe construction activities at the reservoir. General discussions revolve around the construction equipment used, haul road construction, and reservoir site preparation. Specific details concerning the construction of the Horsetooth Dams and Reservoir are provided, followed by a comparison of techniques used at a nearby reservoir that was built shortly after Horsetooth. Finally, the archaeological evidence found at Horsetooth Reservoir for dam construction and related activities is summarized.

5.4.1 Construction Equipment

Early construction and earth moving machinery were large and cumbersome, powered by steam or pulled by livestock, and not very efficient. Road construction helped to change the way construction equipment was used and in turn shaped the way that these machines would evolve into more useful equipment. When the Federal-Aid Highway Act was enacted in 1921, it placed specific requirements on construction methods that put a strain on the existing construction equipment. As more roads were built, new types of equipment were developed and older designs were improved. Power and load capacity increased and steam power was replaced by gasoline, which in turn was replaced by diesel. New equipment to emerge from this road construction phase include the bulldozer, crawler-drawn and self-propelled scraper, motor grader, bottom dump wagon, dump truck, sheepsfoot roller, cable and hydraulic controls, and concrete and asphalt pavers and plants (Haycraft 2000:18).

Before World War II, the majority of the large dams were made from concrete, while earthfill dams were being constructed, but on a lesser scale. The machinery, specifically engine power, capacity loads, and tires were not adequate for use on large scale earth moving and excavation projects. In the 1930s, a new machine emerged that would increase the haul capacity, speed, and lower costs. The wheel tractor-bottom-dump wagon became an integral part of earthfill dam projects in the early thirties. Later toward the end of the decade, another machine also helped to revolutionize the industry (Haycraft 2000:19). The Tournapull, by LeTourneau, was an integrated wheel tractor-scraper that enabled the construction of larger earthfill dams (Haycraft 2000:20).

During World War II, several machine manufacturers produced military equipment for the United States. Some non-military machinery was still being produced by these companies for farming and priority domestic construction projects, but at a lesser scale. Four major military contributors that continued to build domestic equipment were Caterpillar, LeTourneau, Euclid, and International Harvester (Haycraft 2000:103). Their military machines were essentially the same machines built for non-military use, so, as the war wound down, they did not need to change much in order to produce domestic equipment (Haycraft 2000:106).

After the war, construction projects increased in quantity and size. Reclamation was able to resume work on many postponed water projects. Earth and rock fill dams were being constructed on larger reservoir and diversion sites. Due to site and geologic conditions and costs, these dams became preferred over the concrete fill types at many sites. These large projects required many pieces of earth moving equipment and with the removal of war rationing, manufacturers were eager and able to produce the required machinery (Haycraft 2000:21). Construction contractors, who were unable to purchase machinery during the war, began to buy as much equipment as possible to keep up with the increased demand for domestic projects. This post-war era also saw improvements in hydraulic controls and paved the way for the decline in wire rope controls. Another factor in the decline of the wire-controlled shovels was the wheel tractor-scraper. These machines became the main type of equipment on most construction projects involving earth moving. By the 1950s, technological advances in engines, transmissions, and tires helped to establish the dominance of these construction machines in the modern age (Haycraft 2000:23). Manufacturers did not design or develop any new equipment during the war in order to concentrate on production. After the war, several new ideas changed the shape of construction. The loader-backhoe and the hydraulic excavator, introduced in the late 1950s, and the rubber tired front loader in the late 1940s, revolutionized earthmoving and excavation, and provided the foundation for methods still in use today but with better technology (Haycraft 2000:149 and 234).

An increase in large water projects occurred, during the late 1950s to early 1960s. Large earthfill dams were mostly constructed with Caterpillar scrapers, graders, tracked earthmovers, and Euclid scraper and bottom-dumps (Haycraft 2000: 186). As these projects were completed, in the late 1960s and early 1970s, only a limited number of new large water projects were begun. Limited sites and the advent of new environmental laws slowed the progress of large earth moving projects. The new focus was on smaller agricultural and flood control projects (Haycraft 2000: 192). The use of newer products, like the hydraulic excavator and the wheel loader, meant a decrease in the use of tracked vehicles. Tire technology advanced during the 1950s with the introduction of low pressure and wide base off road tires. Tired vehicles offered more maneuverability and increased speed (Haycraft 2000: 236). The next advance in tire technology did not take hold until the 1970s, with the introduction of radial tires that were stronger, and did not overheat like the fiber-based tires. The radial tire, first introduced in 1947, required vehicle manufacturers to redesign their suspension systems due to the stiffer ride the radial tire provided (Haycraft 2000: 237). The late 1970s and mid 1980s saw a downsizing of the construction industry. Economic woes fueled a decrease in the construction and machinery business, but by the 1990s the industry has regained some ground. After the 1970s, advancements in machinery technology had leveled off. Refinements occurred to preexisting machines that included better reliability, increased safety and comfort for the operators, and much better control and maneuverability (Haycraft 2000: 381).

Today’s equipment dwarfs the machinery of fifty years ago. In the 1940s, a twenty-two-ton dump truck would be filled with a six cubic yard wire controlled shovel. A modern 320-ton dump truck is filled today with a fifty cubic yard hydraulic shovel. A scraper in the 1940s would scrape and haul fifteen cubic yards per trip compared to the fifty-four cubic yards or more by today’s standards (Haycraft 2000:380).

5.4.2 Haul Roads

Haul roads are a network of routes that are used to transport materials, usually earth or rock fill, from their borrow area to their location of placement. These roads must be well maintained to decrease repairs to haul vehicles and permit efficient operations. They should also be no more than 15% in grade with limited curves to reduce energy expenditure. Usually these roads have a hard surface so the haul vehicles can reach higher speeds and efficiency (Harris 1981:31). Haul roads are important aspects of the construction process that need to be created before any major excavations on borrow areas or foundations can occur. The cost of building and maintaining these roads is the responsibility of the constructor and can be very expensive, depending on the terrain and distance. The haul roads also figure into the total cost and time involved in a construction project. Haul times from a borrow area to the foundation site is a major concern for construction jobs. Proper planning can insure that dump trucks and scrapers do not sit idle, waiting for their loads, but have a quick and efficient turnaround time (Parker 1971: 53).

5.4.3 Site Preparation

Before a reservoir is filled with water, the area to be inundated may be cleared of trees and other vegetation, topsoil, and man-made structures and/or wastes. This is done for varying reasons including water quality, taste and odor, safety concerns for boating and other recreational activities, to decrease operational problems from debris, and environmental issues with wildlife (Gunnison et al. 1986:8). If vegetation is left at the site, it can have both beneficial and detrimental affects. The vegetation can provide rich nutrients and habitat for fish but the decay of the plant remains reduces the oxygen in the water and can produce an anaerobic environment. Soils that contain organic materials can also add to the anaerobic environment (Gunnison et al. 1986:4). Soils can also impart unwanted minerals into the water and can have detrimental effects to the water quality and have secondary effects on structures and human consumption issues. Metal and other chemicals and minerals in the soil can cause mineral deposits on canals, dam works, ditches, and plumbing; and clothing stains are also an issue. Overall, the vegetation and organic soils cause a reduction in the water quality for human uses (Gunnison et al. 1986:37).

Before the 1960s, most reservoir sites were totally cleared of debris, up to 3 to 5 feet above the normal pool level. The general trend after the 1960s was to clear vegetation from around recreation areas, boat lanes, populated areas, road crossings, and areas directly upstream from the dam embankments. These trends are based more on monetary issues, aesthetics, and recreation issues then on water quality or other concerns (Gunnison et al. 1986:9). Some of the advantages of vegetation cover, such as fish shelters, can be replaced by artificial features without the problems associated with water quality (Gunnison et al. 1986:10).

After initial filling, a five to ten year period of water quality improvement takes place. This process, called “reservoir aging”, is when the organic matter left on the surface has totally decomposed and is no longer releasing nutrients into the water. This results in a drop in fish populations, but this also means that the quality of the water for human consumption and irrigation improves (Gunnison et al. 1986:14). One method to hasten this aging process is to burn the vegetation and trash on the surface before filling. This turns the organic remains into inorganic materials that can be easily removed during the reservoir’s initial filling. This method does not have any impact on organic soils, which may have detrimental impacts to water quality in the initial aging process (Gunnison et al. 1986:15).

Reclamation has required the clearing of waste and debris from reservoir sites. Materials that may clog up the outlet works, such as trees, brush, and loose plant materials were routinely removed. Fences, bridges, buildings, and other man-made features were also destroyed or removed. General specifications include cutting of standing trees to a height of one foot. The timber was salvaged or usually burned, on site. Other loose materials, like vegetable materials and trash over one inch in diameter, were also disposed of by burning. Non-combustible materials were buried under a minimum cover of two feet (USDI Bureau of Reclamation 1957: 277).

5.4.4 Horsetooth Construction Method and Design

The four dams constructed for Horsetooth Reservoir are generally the same type of dam with some minor differences. The dams are earth and rockfill structures with a central impervious zone of compacted clay, sand, and gravel, which is buttressed on both sides with zones of semi-pervious sand and gravel, pervious sand, gravel, and cobbles, rock fines, and rockfill or rip rap. Additional elements of each dam include a concrete cut-off wall and toe drains (USDI Bureau of Reclamation 1946, 1949c, 1949d, 1949e). The design of the Horsetooth Reservoir dams is very similar to the designs of modern earth and rock embankment dams. The major differences are the newly devised internal defensive seepage techniques (filters), foundation treatments to control seepage, and measures to guard against seepage caused dam failures (USDI Bureau of Reclamation 2000b: 1).

The embankments for the dams were designed to deal with three main issues: seepage, stability, and deformation. The dams at Horsetooth Reservoir contain cut-off trenches with concrete cut-off walls and toe drains to decrease any seepage problems (Howard 1998: 242). Foundation stability was accomplished by removal of unstable soil and vegetable material (Figure 5-17). The cut-off zone was also excavated to the bedrock to help with stabilization (Collins and Thomas 1950: 11). Pervious and semi-pervious inner core embankment materials were placed along the parallel axis of the dam using scrapers and dump trucks, with some instances of perpendicular material placement near structures or abutments, and then were leveled with bulldozers. The soil layers were compacted with a minimum of 12 passes of a roller (Figure 5-17). Hard to reach places were compacted with hand/power tamping equipment. Water content of the soil was monitored and controlled to ensure proper moisture for optimum compaction and stability (Collins and Thomas 1950: 23). The outer embankment and riprap zones were also placed parallel to the dam’s axis and spread evenly with bulldozers. The outer embankment materials were compacted by using a water sluicing method and then with machine rollers. Riprap was compacted with sheepsfoot rollers (Collins and Thomas 1950: 30-31).

The earth fill for the embankment was excavated along the central portion of the reservoir valley. The borrow pits were stripped of the topsoil and vegetable materials, to provide a more suitable fill. Scrapers and excavation shovels were both used for borrow pit excavation. Excessively large rocks and debris were removed by hand or separated by heavy machinery. Locations for the borrow pits were kept at minimal distances to the dam where the material would be used, usually directly west of the specific dam and extending north and south along the valley bottom (Collins and Thomas 1950: 21and 22). The materials were mixed on site by using the shovels and draglines to blend the soil layers within their buckets and deposit them in the carryalls and tractors ready to be dumped. In addition, when scrapers were used instead of bucketed excavators, the scrapers ran on a sloped cut to ensure that all layers were gathered for proper mixing (Thomas 1949: 21). Some semi-pervious and pervious materials for Horsetooth and Soldier Canyon dams were excavated from borrow pits located north of the reservoir site near the town of Bellvue, west of the Cache La Poudre River. These materials were much further

Figure 5-17. Foundation Clearing at Top, Looking South, and Compaction Work at Bottom, Looking North, at Soldier Canyon Dam (Top photo by A.E. Thompson, 9-26-1946; bottom photo by A.E. Thompson, 6-18-1948).

away, between 3.3 and 4.3 miles, than the materials located in the reservoir valley (Collins and Thomas 1950: 10; Thomas 1949: 25). The quarries used to produce shell and riprap materials were mostly located on the west side of the reservoir and utilized the Lyons sandstone formations, Dixon Canyon and Spring Canyon Dams did use some Dakota Sandstone formations located on the east side of the valley adjacent to the dam site. The sandstone outcroppings along both sides of the valley allowed the quarries to be located very close to the dam sites. New quarries were opened, historic sandstone quarry cuts were utilized, and some historic sandstone quarry tailings piles were used for rock fines and riprap materials (Field and Hill 1949: 10).

Haul roads were built and maintained with bulldozers. These roads were simply leveled with the bulldozer and kept moist with the water trucks to reduce dust. The bulldozers would periodically grade the roads to remove any wheel ruts or anomalies caused by the haul trucks and other equipment (Collins and Thomas 1950: 22). Extra haul roads and benches were necessary at some of the rock quarries due to the safety concerns of working on sloping hillsides (Field and Hill: 43).

The design and construction of the dams at Horsetooth Reservoir are very similar to the design and construction methods being used today. The two major differences are the use of specific defensive measures against seepage and dam stability, and the types of construction equipment used (Table 5-4). The design features that the Horsetooth Reservoir dams do not have are a filter zone and foundation buttresses. The filter zone or blanket is made of specific sands and gravels and are sized to allow for the passage of seepage water while preventing the erosion of the dam's internal core. These filters are located on the downslope side of the dam next to the impervious zone and extend from the dam's base to its crest (USDI Bureau of Reclamation 2000a: 6). The use of these filters was not common practice during Horsetooth Reservoir's construction, but are now being installed at Horsetooth as part of the current Safety of Dams Project. The filter became a design feature in Bureau of Reclamation earthen dam projects in the 1960s (USDI Bureau of Reclamation 2000a: 2). The foundation buttresses are located on the downstream toe of the dams and are included to help stabilize the dams, especially in regards to earthquake activity (USDI Bureau of Reclamation 2000c: 2).

5.4.5 Construction Comparison

Contemporaneous dams are overall very similar in design and construction techniques to those used at Horsetooth. One example, Carter Lake, is a natural lake that was enlarged with earth and rockfill dams and fed by a canal. Similar to Horsetooth Reservoir, in being a Colorado eastern slope storage reservoir, it has three dams and a capacity to hold 112,200 acre-feet, at normal water surface elevation (USDI Bureau of Reclamation 1957: 61). Both reservoirs were built as part of the Colorado Big-Thompson Project.

TABLE 5-4.
CONSTRUCTION EQUIPMENT USED AT DIXON CANYON.

Equipment Type	Year Produced	Cubic Yards Capacity	Quantity
Excavation			
Lorain Shovel Model 77	1935	1 ½	1
Manitowoc Shovel Model 3500	1946	2 ½	2
LeTourneau Carryalls Model FU	1942	18	4
D-8 Caterpillar Tractors (to pull carryalls)	1942	N/A	3
D-8 Caterpillar Tractor (to pull carryalls)	1947	N/A	1
LeTourneau Tournapull Model H	1942	8	3
D-8 Caterpillar Tractor with LeTourneau Dozer Blades	1942	N/A	1
Hauling			
Euclid Bottom-Dump Trucks Model 4LDT	1940	16	9
Euclid End-Dump Trucks Model 5FD	1939	13	5
Euclid End-Dump Trucks Model 27FD	1946	10	1
Euclid End-Dump Trucks Model 49FD	1948	10	2
Sprinkler Truck 3,000 Gallon	1943	N/A	1
International C-60 Sprinkler Truck 1,800 Gallon	1935	N/A	1
Placing			
D-8 Caterpillar Tractors with Dozer Blades and Scarifiers	1942 and 1946	N/A	4
D-8 Caterpillar Tractors with rock-rakes	1942	N/A	2
McCoy (USBR) Rollers (pulled by D-8 Caterpillar)	1946-1947?	N/A	4
D-12 Caterpillar Motor Graders	Unknown	N/A	2

(Source: Field and Hill 1949: 52, 56-57)

Carter Lake Reservoir's embankment materials were obtained from borrow areas within the reservoir site and adjacent to the dams. Rock fill materials were also located near the dam sites and were about 2,000 feet away (USDI Bureau of Reclamation 1957: 205). The close proximity of the borrow areas made for short haul distances and quicker load turn around. Like Horsetooth's dams, Carter Lake incorporated toe drains, cut-off trenches and walls, and grouting to help with seepage problems (USDI Bureau of Reclamation 1957: 66). The materials for the dam consisted of an impervious core with a zone of rock fines and then a zone of rock fill. This was done to both the upstream and downstream side of the dams (USDI Bureau of Reclamation 1957: 232). The dams at Horsetooth Reservoir are made of an impervious core, with zones of rock fines, pervious or semi-pervious materials, and rock fill. Only Horsetooth, Spring Canyon, and Soldier Canyon Dams contained all four materials, while Dixon Canyon Dam omitted the pervious zone (USDI Bureau of Reclamation 1946, 1949c, 1949d, 1949e). The total cost to build Carter Lake Reservoir was $3,581,000. The average labor force used was 96 people, with a maximum of 170. Construction began in June 1950 and ended in November 1952 (USDI

Bureau of Reclamation 1957: 173). Horsetooth Reservoir had a total cost of $12,565,000. The labor force ranged from a low of 165 workers to a maximum of 692. Construction began in 1946 and continued into 1949 (USDI Bureau of Reclamation 1957: 173-174).

One of the main differences in the two reservoir projects is the size of the dams and the amount of earth and rock used. At Carter Lake, there are three dams. Dam Number 1 has a crest length of 1,235 feet, crest width of 40 feet, and a height above the original lowest point in the foundation of 214 feet. Dam Number 2 has a crest length of 1,150 feet, a crest width of 30 feet, and a maximum height above the original foundation of 75 feet. Dam Number 3 has a crest length of 1,425, crest width of 40 feet, and a height above the original foundation of 55 feet (USDI Bureau of Reclamation 1957: 66). The total amount of earth and rock material for all three dams is around 3.3 million cubic yards (USDI Bureau of Reclamation 1957: 205-206). Horsetooth's dams are much larger and contain larger quantities of earth and rock. Horsetooth Dam has a crest length of 1,600 feet, a crest width of 35 feet, and a maximum height above the lowest point in the foundation of 154 feet. Soldier Canyon Dam has a crest length of 1,424 feet, crest width of 40 feet, and a maximum height above original foundation of 234 feet. Dixon Canyon Dam has a crest length of 1, 235 feet, crest width of 40 feet, and a maximum height of 240 feet. Spring Canyon Dam has a crest length of 1,150 feet, a crest width of 40 feet, and a height above the foundation of 215 feet (USDI Bureau of Reclamation 1957: 75; U.S. Government Printing Office 1962). Total volume of materials for the dams at Horsetooth Reservoir is 10,139,000 cubic yards. Soldier Canyon Dam alone had volume of 3.2 million cubic yards (Mermel 1963: 86-88).

5.4.6 Archaeological Evidence of Dam Construction and Related Activities

Several types of features related to the construction of the reservoir were evident within the reservoir valley when it was surveyed in 2000 (Mutaw 2001). The majority of these features are haul roads, borrow areas, and rock quarries. Site 5LR759 includes Horsetooth Dam and Reservoir and all of the other dams and features related to it and solely to its construction and operation. Figure 5-18 is a map of the reservoir area showing the borrow areas and haul roads used during construction. The construction features located and designated as being a part of the Horsetooth Reservoir and dams include; haul roads associated with Spring Canyon Dam (Features 36 and 64[details concerning individual feature numbers can be found in Mutaw 2001]), rock fines quarry for Soldier Canyon Dam (Feature 9), haul roads associated with Soldier Canyon Dam (Features 45, 55, and 59), haul roads associated with Horsetooth Dam (Features 50, 51, and 52), and water level slope gauges (Feature 49). A previously recorded site, 5LR1343, not originally assigned as being associated with the dam construction, is the riprap rock quarry and associated haul roads for Soldier Canyon and Horsetooth dams. Other sites that likely originated from the reservoir construction include rock fines from historic sandstone quarry tailings piles and quarry cuts at sites 5LR1413 and 5LR1416; rock fines for Dixon Canyon Dam from sites 5LR1334, 5LR1335, 5LR1336, north end of 5LR1426 and 5LR1427; 5LR9954, 5LR9955, and 5LR9957; riprap for Dixon Canyon Dam from sites 5LR1335, 5LR1336, and 5LR9958.

About three-quarters of the Zone 2 rock fines for Spring Canyon Dam were extracted from historic sandstone quarry waste piles, located 1½ miles south of the dam site (Figure 5-19 and Figure 5-20). Zone 2 is a filter layer between the impervious core of the dam and the pervious outer rip rap layer. Zone 2 is made of the smaller rock fines that are compacted in twelve-inch layers. Some of the rock tailings contained too much fine-grained soil, which would make the rock layer too impervious.

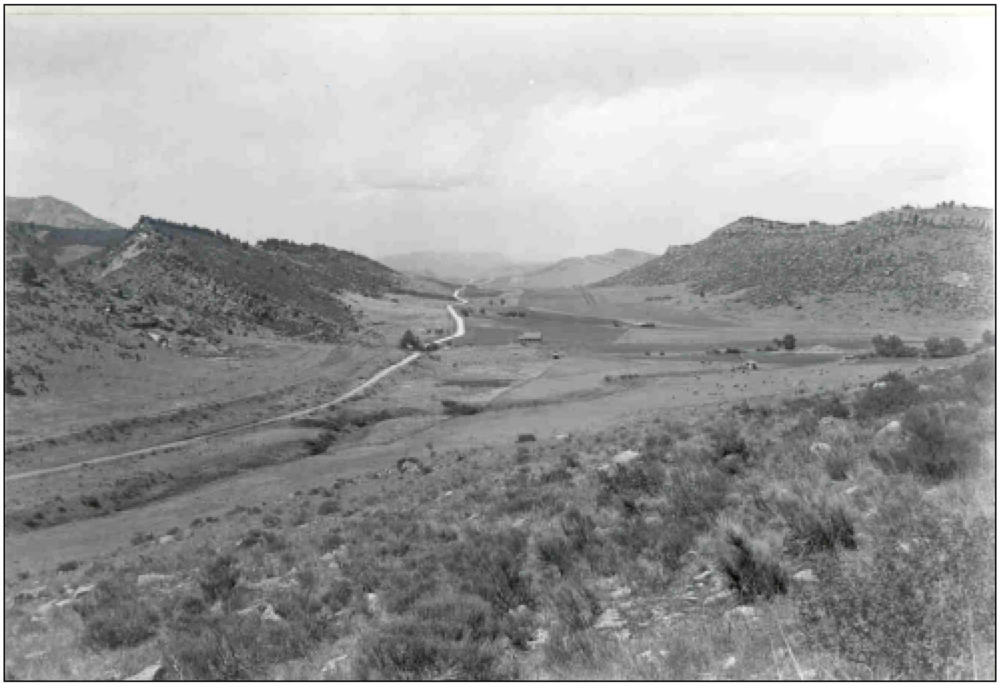


Figure 5-19. View of Reservoir Site in 1946 Before Construction Began, Looking North. Spring Canyon Dam on Right (Photo by A.E. Thompson, 6-28-1946).

Figure 5-20. View of Reservoir Site in 1947, Looking North, after Construction had Begun. Note Borrow Area to the Left (5LR1416) and Clearing Work on the Valley Floor, not Visible in Figure 5-18 (Photo by A.E. Thompson, June 1947).

5LR759, Feature 45, runs perpendicular to this site at its north end, and may be related to the quarry cuts of this site. There is also a road bed, Site 5LR759, Feature 59, that is located south of Soldier Canyon Dam along the eastern side of the valley. This road bed may be associated with the hauling of the impervious and semi-pervious soil fill removed from the borrow areas in the middle of the valley.

Horsetooth Dam used Site 5LR1343 for its rock fines and riprap embankment materials on both the upstream and downstream sides (Figures 5-21 and 5-22) (Collins and Thomas 1950: 31). The site has several connected road beds leading up to the quarry face and one road bed extending east, which appears to connect to other road beds leading to the east Horsetooth Dam abutment (5LR759 Features 50-52) and road beds going to the north abutment for Soldier Canyon Dam (5LR759 Feature 55). It now appears in retrospect, that many of the features identified during the surveys in the 1990s and 2000 as railroad side tracks and road beds associated with the 1880s-1900s quarrying era, are actually haul roads related to the construction of the dams.

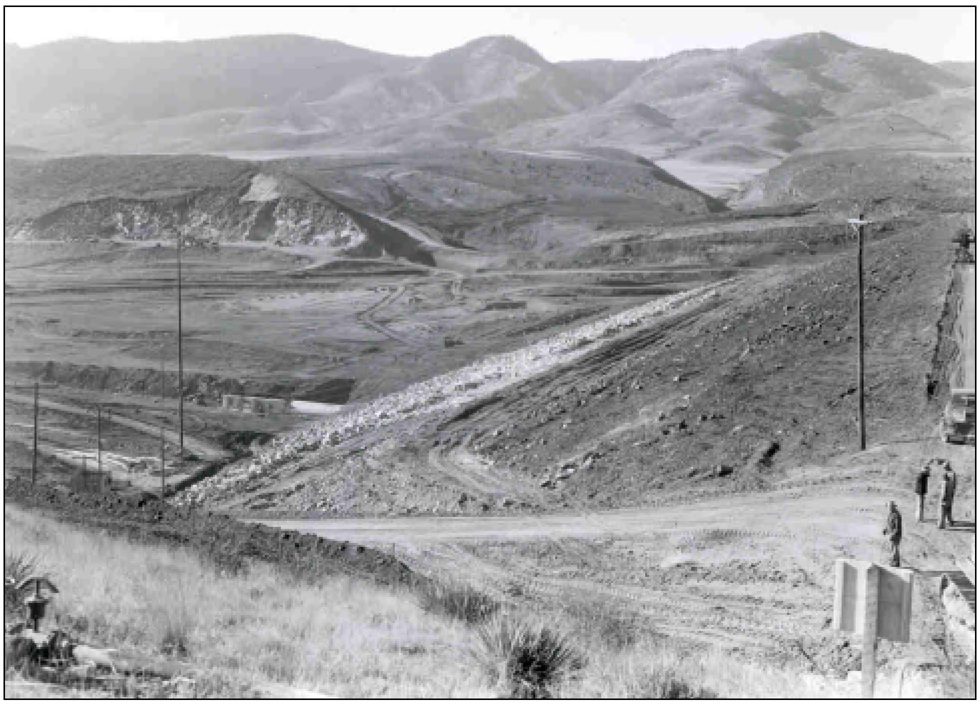


Figure 5-21. View Along Axis of Horsetooth Dam, Showing Rock Quarry Site 5LR1343 in Background to Left, Looking West. Note also Haul Roads from Quarry Leading to Right Abutment in Foreground (Photo by A.E. Thompson, 12-16-1948).

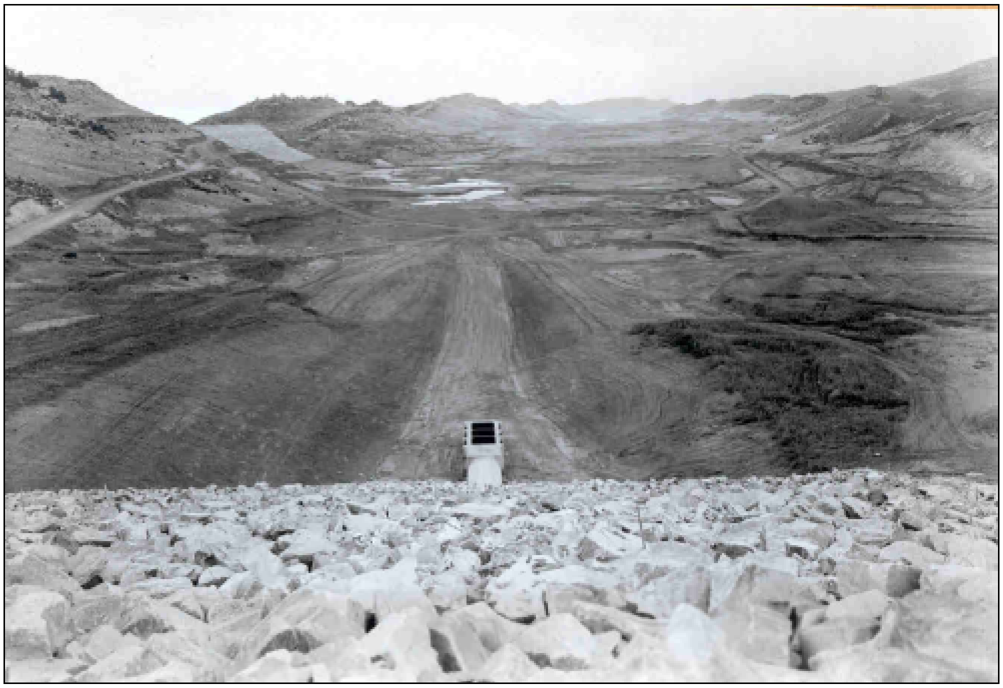


Figure 5-22. View of Reservoir Site from Horsetooth Dam, Looking South. Note Haul Roads Leading from Site 5LR1343, at right, to Soldier Canyon and Horsetooth Dams. Soldier Canyon Dam at Top Left of Photo (Photo by A.E. Thompson, 7-26-1949).

In summary, the techniques used to construct Horsetooth Reservoir were similar to those used to construct contemporaneous reservoir projects. The length of material haul distances was a main concern for construction during this period, given the limitations of the equipment that was used. Modern construction projects tend to focus more on material quality than haul distances because the modern equipment can haul substantially more material with each load. One distinguishing feature of Horsetooth Reservoir, that was probably not an element of most reservoirs, was the need for an equalization channel at the bottom of the reservoir. Most reservoirs are constructed along a single drainage with the water pooling in a single basin behind the dam. In the case of Horsetooth Reservoir, three drainages were blocked, with an additional dam with the outlet works placed perpendicular to the three other dams. This created a situation in which three separate pools would be formed behind the dams on the drainages. In order for these pools to connect, and for all of the water in the reservoir to be able to flow to the outlet works, a channel across the bottom of the reservoir had to be excavated. The channel provides a means for water to flow from one pool to another and ultimately to the outlet works, thus equalizing the pool level of the reservoir.